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Nitrogen-Fixing Biological Inoculant for High-Yield Cereal Crop Production

ICF Case Study: Illustrative Potential, Planned and Realised Avoided Emissions Assessments

The Impact Convergence Forum for Private Equity (ICF) is a collaborative group of firms with private equity impact strategies, working to encourage convergence in impact measurement and management practices among LPs and GPs — supporting high-integrity practice while enabling better decision-making.

This case study was developed by members of the ICF during a 2024–25 Project Frame Content Working Group to showcase practical considerations in forward-looking and realised avoided emissions assessments. It is illustrative only and does not constitute commercial, legal, financial or investment advice. The case study is intended to surface methodological considerations, not to prescribe a standard or endorse any specific tool, company or framework.

June 2025

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Impact Report

Summary and Context

This case study presents three avoided emissions impact assessments for nitrogen-fixing biological inoculant (NFI) solutions: two forward-looking estimations — Potential Impact and Planned Impact — and one backward-looking assessment of Realised Impact. These assessments focus on the role of NFI solutions as a partial replacement for synthetic nitrogen fertiliser use in high-yield cereal crops such as corn, wheat and sorghum.

Scope of the Problem. Synthetic nitrogen fertilisers ('synthetic N-fertilisers') such as anhydrous ammonia, urea and urea ammonium nitrate are essential for high crop yields but significantly contribute to GHG emissions, air and water pollution, and soil degradation. In 2018, their production, transport and use accounted for 1.13Gt CO_2e, representing 10.6% of agricultural emissions and 2.1% of total global GHG emissions.[1] These emissions arise principally from the energy-intensive Haber-Bosch process used to produce ammonia and the substantial direct and indirect nitrous oxide (N_2O) emissions from the field-applied fertiliser. With less than 50% of applied nitrogen fertiliser absorbed by crops, the remainder is lost to the environment through ammonia volatilisation (NH_3), nitrate leaching and runoff (NO_3), and microbial conversion to N_2O.[2,3]

The IPCC identifies synthetic N-fertilisers as a major contributor to N_2O emissions,[4] a potent GHG with a global warming potential approximately 273 times that of CO_2 over a 100-year period.[5] Demand is expected to increase 50% from the 2012 level by 2050,[6] leading to more nitrate runoff, increased N_2O emissions and greater reliance on liquefied natural gas, a key feedstock for ammonia production. While green ammonia may contribute to reduced synthetic fertiliser manufacturing emissions over time, the significant climate impact of direct and indirect N_2O emissions from fertiliser use in fields will still need to be abated by alternative low-emission solutions to synthetic fertilisers, such as those represented in this case study.

NFI Solutions. This illustrative case study examines nitrogen-fixing inoculant (NFI) solutions developed by Pivot Bio, which use non-transgenic, gene-edited bacteria to enhance biological nitrogen fixation in cereal crops like corn, corn silage, wheat, sorghum and other small grains. Applied either on-seed or in-furrow, these microbial inoculants colonise plant roots and convert atmospheric nitrogen (N_2) into plant-available ammonia (NH_3), providing a continuous nitrogen source throughout the growing season. While NFI products are not yet a full substitute for synthetic nitrogen fertilisers, they enable a partial yet

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[1] Menegat, S., Ledo, A. & Tirado, R. Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture. Sci Rep 12, 14490 (2022). https://doi.org/10.1038/s41598-022-18773-w

[2] Gardner, J.B. and Drinkwater, L.E. (2009). "The fate of nitrogen in grain cropping systems: a meta-analysis of 15N field experiments." Ecological Applications, 19: 2167-2184. https://doi.org/10.1890/08-1122.1

[3] Griesheim, K.L., Mulvaney, R.L., Smith, T.J., Henning, S.W. and Hertzberger, A.J. (2019). "Nitrogen-15 Evaluation of Fall-Applied Anhydrous Ammonia: I. Efficiency of Nitrogen Uptake by Corn." Soil Science Society of America Journal, 83: 1809-1818. https://doi. org/10.2136/ sssaj2019.04.0098

[4] https://www.ipcc.ch/report/ar6/wg3/chapter/chapter-7/

[5] https://ghgprotocol.org/sites/default/files/2024-08/Global-Warming-Potential-Values%20%28August%202024%29.pdf

[6] FAO. 2018. The future of food and agriculture – Alternative pathways to 2050. Rome. 224 pp. License: CC BY-NC-SA 3.0 IGO

meaningful (15–30%) reduction in synthetic nitrogen application rates per acre without compromising crop yields. The resulting avoided emissions vary depending on the fertiliser type replaced, the extent of reduction, site-specific conditions (soil type, climate) and grower practices. By displacing a portion of synthetic nitrogen, NFI solutions help reduce GHG emissions, nitrogen runoff and other environmental impacts associated with conventional fertiliser use.

Purposes of the Avoided Emissions Assessments. This case study is intended to provide instructive, practical examples of avoided emissions assessments conducted before an investment decision (ex-ante) and during the investor hold period. It demonstrates a progression of learning and methodological refinement over time:

- **Potential Impact (2022-2050)**: An early-stage, ex-ante estimate of the potential impact of the novel NFI Solution technology on US corn acres, developed for internal diligence using initial assumptions and limited data.
- **Planned Impact (2024-2029)**: A forward-looking estimate incorporating a refined 2024 GHG methodology, commercial growth projections and conservative assumptions on grower adoption and nitrogen reduction behaviours. Used internally for target-setting and performance measurement.
- **Realised Impact (2022, 2023, 2024)**: A year-over-year assessment based on grower-reported data on synthetic nitrogen reductions and product use. Supports sustainability reporting, investor disclosures, customer engagement and validation of a Nitrogen Credit programme, reflecting increasing data specificity and alignment with field-level practices.

Opportunity for Emissions Avoidance. The analyses that follow provide an example of how different avoided emissions assessments — Potential, Planned and Realised Impact — can inform understanding of a solution's climate impact over time. Each assessment is designed with distinct methodological choices that aim to align with Project Frame and WBCSD guidance and principles for transparency, relevance and conservatism. A Potential Impact analysis (2022–50) models a speculative scenario in which 40lbs/acre of synthetic nitrogen fertiliser is partially replaced with nitrogen-fixing inoculants (NFI) across all US corn acres, suggesting the potential for up to 10 million t CO_2e in annual avoided emissions by 2050. The Company's Planned Impact analysis (2024–29) estimates that its commercial growth strategy could deliver between 0.5 and 0.8 million t CO_2e in avoided emissions across participating US corn acres in 2029. The Realised Impact analysis estimates 567,035 t CO_2e in avoided emissions across the 2024 growing season.

These estimates, their underlying assumptions and the methodological choices that shaped them — such as functional units, system boundaries, allocation decisions and emissions factors — are detailed in this case study to foster transparency and comparability.

Impact Pathways

Primary Impact Pathway(s). NFI solutions and synthetic nitrogen fertilisers deliver nitrogen to crops in fundamentally different ways, which affects how they are assessed in ISO 14040-compliant lifecycle assessments. For a valid avoided emissions analysis, a common functional unit — 'kg of nitrogen delivered per acre' — is required to compare emissions impacts fairly. Synthetic fertilisers supply chemically manufactured nitrogen directly to the field, measured as 'kg of fertiliser applied,' convertible to 'kg of nitrogen' based on molecular weight and application rates. In contrast, NFI solutions involve living microbes that fix atmospheric nitrogen at the root, making their LCA functional unit the product itself (package of microbes applied per acre), rather than the nitrogen mass delivered.

The primary impact pathway for avoided emissions is the ***partial replacement of synthetic nitrogen fertiliser (kg N replaced per acre)*** with biologically-fixed nitrogen supplied by microbial inoculants (NFI solutions), avoiding GHG emissions across manufacturing and field application stages:

- Manufacturing CO_2e emissions (avoided). NFI solutions reduce cradle-to-gate manufacturing emissions by displacing a portion of synthetic N-fertiliser applied per acre. The emissions difference between manufacturing synthetic fertilisers and NFI solutions is significant. A 2024 third-party LCA estimates NFI solutions can deliver up to 40lbs (18kg) of synthetic nitrogen equivalent per acre via biological nitrogen fixation, with an average replacement rate of 15kg per acre. Cradle-to-grave emissions for NFI solutions range from 0.475 to 0.670kg CO_2e per acre, depending on whether the product is applied as Liquid in Furrow (LIF) or On Seed (OS). By contrast, delivering 15kg N from synthetic fertilisers results in far higher emissions: 43.2kg CO_2e for anhydrous ammonia (EF 2.88kg CO_2e/kg NH_3), 57.6kg CO_2e for urea (EF 3.84kg CO_2e/kg urea), or 68.4kg CO_2e for UAN (EF 4.56kg CO_2e/kg UAN).[7] The avoided emissions per treated acre are calculated by subtracting NFI solution emissions from the synthetic N-fertiliser emissions displaced.
- Field N_2O emissions (avoided). There are significant direct and indirect N_2O Emissions that result from the application of synthetic N-fertilisers. The 2024 LCA for Pivot Bio NFI solutions estimates negligible field emissions, further validated by independent research studies. However, synthetic N-fertiliser in-field application generates both significant direct and indirect emissions. Direct emissions occur due to microbial processes in the soil. When synthetic N-fertilisers are applied to croplands, they undergo nitrification and denitrification, releasing N_2O as a byproduct. Indirect emissions occur when nitrogen is lost from the field through volatilisation, leaching or runoff, later contributing to N_2O formation elsewhere in the environment. Estimated direct and indirect field emission rates in accordance with IPCC AR6 methodology (2019) suggests field emissions range between 0.0055 and 0.0421kg N_2O-N/kg N-fertiliser in direct and indirect emissions, depending on the soil humidity class, soil drainage class and location (disaggregated). Replacing synthetic N-fertilisers with microbial inoculant can therefore reduce the associated direct and indirect emissions of nitrous oxide (N_2O) losses from soils due to decreases in synthetic nitrogen application rates.
- Impact dependent on grower decisions. Realised avoided emissions depend not just on product sales but on growers actively reducing synthetic N-fertiliser use. Therefore, avoided emissions estimates must be supported by both sales data and qualitative/quantitative evidence from growers showing reductions in synthetic N use. The Potential Impact analysis estimates long-term benefit based on conservative assumptions and projected adoption, while Planned and Realised Impact analyses refine assumptions based on actual grower behaviour and field-level data.

Solution Relevance to Business Sustainability Strategy. NFI solutions represent 100% of the company's revenues. A cradle-to-grave 2024 Lifecycle Analysis (LCA) found very limited adverse climate impacts from product manufacturing and use. Additional potential side effects and co-benefits are discussed under Challenges and Side Effects.

Solution Relevance to End-Markets. NFI solutions are considered to be a Direct Product (Frame) / End-Use Solution (WBCSD) used by growers to replace a portion the nitrogen provided by synthetic N-

[7] Argonne GREET R&D Model (anl.gov), 2023 v1

fertilisers with a lower-carbon intensity, biologically-fixed nitrogen delivered by microbes. NFI Solutions are considered a partial replacement for existing demand, enabling growers to reduce the application amount of synthetic N-fertilisers such as anhydrous ammonia, urea or urea ammonium nitrate (UAN), among others.

Regulation. While there are no regulations specifically encouraging the application of NFI solutions in the markets served, various regulatory bodies globally are considering policies to encourage climate smart / sustainable / low-carbon agricultural production practices. Such policies, where they overlap with product registration and availability, could offer a tailwind to further accelerate adoption. In the event that regulation mandates NFI solution use, the reference scenario should be re-examined to reflect both the enabling effect of the regulation and the anticipated pace at which the mandated standard becomes business-as-usual, in line with WBCSD guidance to reference the market average mandated product. At this stage the company has not evaluated or quantified the potential impact on avoided emissions calculations under this hypothetical scenario and notes this is an area for further examination should a regulatory mandate be considered more likely.

Model Overview

This case study illustrates two forward-looking calculation methodologies and one backward-looking methodology that were developed across an investment lifecycle and reflect a progression of learning and updated assumptions over time. The underlying model for each calculation remains the same, but with nuances in assumptions (emissions factors, specificity levels) with improvements to methodological approaches. The methodology illustrated in this case study was developed by Pivot Bio, with initial support from Generation Investment Management, to quantify the GHG reductions from nitrogen fertiliser displacement during a growing season. Below is a brief summary of the case study elements, further described in this and subsequent sections.

Table 1: Case Study Overview

CATEGORY	DESCRIPTION
SOLUTION DETAILS	
Who is claiming the avoided emissions?	Solution provider - producer of the nitrogen-fixing biological inoculant (NFI)
Solution Type	Direct product - used by growers in the production of cereal crops
Market assessed	US cereal crop production - primarily corn and wheat
How is the solution implemented?	Applied either as a liquid (LIF) or as a rehydrated powder on seeds (OS), these microbes colonise plant roots, feeding on plant sugars and naturally delivering nitrogen throughout the growth cycle.
ELIGIBILITY GATES	
Gate 1 Climate Action Credibility	The company is a pure player, with 100% of revenues tied to the solution. While Scope 1–3 emissions are reported annually, decarbonisation targets are not yet disclosed or validated.
Gate 2 Latest Climate Science Alignment	NFI Solutions align with IPCC AR6 recommendations by reducing reliance on synthetic N-fertilisers — a major source of N_2O emissions — and improving nitrogen use efficiency (NUE) through a more consistent, plant-accessible nitrogen supply that minimises volatilisation, leaching and runoff.

Table 1: Case Study Overview

CATEGORY	DESCRIPTION
Gate 3 Contribution Legitimacy	• Decarbonising Impact: YES — reduces CO_2 and N_2O emissions per acre • Direct Impact: YES — independent studies confirm NFI delivers nitrogen effectively to cereal crops while maintaining or improving yields • Significant Impact: YES — third-party LCA indicates NFI replaces ~15kg synthetic nitrogen per acre, with just 0.67 kg CO_2e emissions per acre, compared to 43–68kg CO_2e for synthetic alternatives
REFERENCE AND TIMEFRAME	
Reference Solution Selection	• Potential Impact: Conventional ammonia (dynamic, 2022–50), aligned with IEA SDS scenario for increasing green ammonia share • Planned Impact: Conventional ammonia (constant, 2024–29) • Realised Impact: Market mix of synthetic N-fertilisers based on self-reported grower data
Required by regulation	No
Type of Substitution	Existing demand: Partial Replacement. NFI solutions enable the reduction in application rate (15–30%) of synthetic N-fertilisers while maintaining (or improving) crop yields.
Timeframe	Microbial inoculants and synthetic fertilisers are generally produced, purchased and consumed within a given year / growing season. Time boundaries of the three analyses are: • Potential Impact: Forward-looking, 2022–2050 • Planned Impact: Forward-looking, 2024–2029 • Realised Impact: Backward-looking, year-on-year for 2022, 2023, 2024
SYSTEM BOUNDARY AND FUNCTIONAL UNIT	
System boundary	Cradle to field, covering production through in-field application, excluding downstream crop use (assumed equivalent for solution and reference).
Functional unit	• Solution functional unit (per LCA): One package of PROVEN 40™ applied to farmland, covering 40 acres (LIF) or 117.5 acres (OS). Converted to *kg of Nitrogen Delivered per Acre* for comparison. • Reference functional unit: *Kg of Nitrogen Replaced per Acre* - based on the difference between the current synthetic N-fertiliser mix and the prior same-crop year, assuming limited variability in nitrogen application rates over the past three years.
Lifecycle stages / process focus for GHG emission calculation	• Solution - Production, transport and application of the microbial inoculant, including end-of-life disposal of all packaging • Reference - Production, transport and application of the synthetic fertilisers (disaggregated by type), including direct and indirect field N_2O emissions

To calculate the GHG impact of the NFI solutions, we assess the manufacturing, direct and indirect field emissions associated with both the conventional use of synthetic N-fertilisers and the avoided emissions from substituting them with NFI solutions. Wherever practicable, this is done at the grower (field) level to more accurately reflect both composition of the nutrient management plan as well as factors such as soil, climate and location that may affect choice of emissions factors. For each grower (acre), we consider the stated reduction in synthetic Nitrogen fertiliser use in the current crop year as compared to the most recent crop-year baseline, along with the breakdown of synthetic N-fertiliser reduced (conventional ammonia, UAN, urea, nitric acid, ammonium nitrate or ammonium sulfate). This prior year point of reference was chosen for practical reasons after considering the potential use of a prior three- and six-year averages, which did not yield statistically significant differences. We apply manufacturing emissions factors and determine tonne GHG / tonne N-fertiliser for each fertiliser type to estimate the reference case for the reduced synthetic N-fertiliser.

Emissions Reduction Calculation. The total avoided emissions (ΔGHG) per field (acre) in the cradle-to-field analysis are calculated using the following equation (see step-by-step model construction for more detail on specific emissions factors and grower data sources):

$$\Delta GHG = \Delta GHG\_M + \Delta GHG\_N_2O$$

Where:

- **ΔGHG_M**: Reduction in fertiliser manufacturing emissions = replaced synthetic N manufacturing emissions – NFI solution manufacturing emissions. The manufacturing emissions intensity of synthetic N-fertilisers is well documented, although it varies by production method.
- **ΔGHG_N_2O** = Reduction in direct and indirect soil N_2O emissions that result from the reduction in Synthetic N. Given the high variability of direct and indirect N_2O emissions across climate, soil type and location, we use IPCC Tier 1 and IPCC Tier 2 disaggregated emissions factors (direct (EF1) and indirect (EF4, FracGASF, EF5, FracLEACH -(H)), for realised impact calculations and aggregated emissions factors for potential and planned impact calculations. These direct and indirect Tier 1 and Tier 2 emissions factors are further explained in Step-by-Step Model Construction below, and reflect a choice to use more specific regional variables (Tier 2) where available.

Solution Maturity and Technical Alternatives. There is a growing market for biostimulants in agriculture that includes beneficial bacteria/fungi, N-fixing biological inoculants (NFI), organic acids (humic/fulvic acid), protein hydrolysates (amino acids) and seaweed extracts and botanicals. Among these, NFI solutions are the most common and include those offered by Pivot Bio. In 2023, an estimated 27% of US growers surveyed used one or more biostimulants on their fields, and 7% used the company's NFI solutions.[8] The NFI solutions referenced in this case study are sold at price parity with the lowest cost synthetic-N fertiliser in order to encourage adoption and use. As with many agricultural inputs, grower education, familiarity with the product and confidence in its performance are critical to scaling uptake. Demonstration trials, agronomic support and peer-to-peer learning often play key roles in building trust and ensuring successful integration into existing farm management practices. In addition to Pivot Bio products (PROVEN40 and RETURN products), competitor NFI solutions include ENVITA (Azotic Technologies), SOURCE (Sound Agriculture) and UTRISHA N (Corteva Agriscience), among others. This illustrative case study was developed with referenced LCA emissions for Pivot Bio products but does not include information from competitor products. These products are novel technologies that are recently commercialised, with Pivot Bio NFI solutions first released in 2019 for corn and 2020 for wheat.

Key Assumptions and Limitations

As this case study reflects three separate sets of analyses, we summarise the key assumptions by impact analysis in Table 2, with further explanation below.

[8] Stratus Ag Research (2023). Tracking Biostimulants Grower Survey - USA and Canada 2023. https://stratusresearch.com/reports/survey-2023-biologicals/

Table 2: Key Assumptions by Assessment Type

	POTENTIAL IMPACT	PLANNED IMPACT	REALISED IMPACT
System Boundaries	US Corn, cradle-to-field (N_2O included)		
Time Horizon	2022–50 (forward-looking)	2024–29 (forward-looking)	2022, 2023, 2024 (backward-looking,year-on-year)
Solution Scenario	Forecasted adoption curve, 40 lbs N/acre application rate	Commercial growth scenarios (2%, 4%, 6% CAGR), by acres, application rate, % of growers above application threshold	Market avg. field-level application (self-reported)
Solution Emissions Factor	0.23kg CO_2e/kg N (2021 estimate)	0.54kg CO_2e/acre (2024 LCA)	0.475–0.670kg CO_2e/acre (LIF/ OS)*
Reference Scenario	Partial synthetic N (ammonia) replacement at 40lbs/acre (constant)	Partial synthetic N (ammonia) replacement at 35lbs/acre, modelled growth	Partial synthetic N replacement (ammonia, UREA, UAN mix, grower-reported)
Reference Emissions Factor (Cradle-to-Gate)	2.59kg CO_2e/kg N (ammonia) 0.23kg CO_2e/kg N (green ammonia) dynamic weighted avg.	2.88kg CO_2e/kg N (ammonia)	3.78kg CO_2e/kg N (2024 market mix)
Reference Emissions Factors (Direct and Indirect Field N_2O)	State-specific (FastGHG)	State-specific (IPCC + Lawrence 2021)	State-specific (IPCC + Lawrence 2021)

* *Emissions factors specific to application type (liquid in furrow, LIF or On Seed, OS) based on updated LCA. **Nitrogen Credit programme participants use 2024 LCA-derived emission factor as part of programme assumptions.*

System Boundaries and Lifecycle Stages. For all three analyses, the system boundary is set to Corn Production in the United States. The following lifecycle stages are included (or excluded), with the emissions breakdown for NFI solutions:

Table 3: Lifecycle Stages and Rationale for Inclusion

LIFECYCLE STATE	REFERENCE Synthetic N-Fertilzers	SOLUTION NFI Solutions	RATIONALE
Raw Material Extraction	**Included** – Natural gas extraction for SMR feedstock.	**Included** – minimal raw materials for microbial growth media.	Includes all upstream and manufacturing emissions for production and transport to the farm gate. Emissions are primarily driven by the energy-intensive Haber-Bosch process.
Production / Manufacturing	**Included** – SMR + Haber-Bosch process for ammonia synthesis.	**Included** – Microbe production in lab + scaled-up fermentation + formulation.	
Intermediate Transport	**Included** – Ammonia transported from plant to farm gate.	**Included** – Air and truck transport of vials, intermediary products between WIP facilities and to packaging warehouse.	
Packaging	**Included** – minimal in GREET's Cradle-to-Farm Gate	**Included** – Packaging of liquid bladders, OS powder and extender into secondary packaging (cardboard).	
Distribution / Transport to Farms	**Included** – Transport of ammonia to farm gate.	**Included** – Truck transport of final product (LIF or OS) to farms.	
Use Phase / Field Application	**Included** – using FastGHG tool (Potential Impact) and IPCC Tier 1 and Tier 2 emission factors (Lawrence et al (2021)) for Planned and Realised	**Included** – minimal application via seed treatment and in-field BNF during crop growth; no direct N_2O emissions.	Captures significant N_2O emissions from synthetic fertilisers due to volatilisation, leaching, and runoff—impacts not present with NFI solutions.
End-of-Life	**Excluded** – GREET stops at farm gate; packaging disposal outside boundary.	**Included** – minimal microbes degrade naturally in field (per unpublished Pivot Bio data); packaging disposal included.	Included in LCA; end-of-life emissions are minimal (<2.2% of total for NFI). Packaging disposal not modelled due to negligible impact.

Time horizon. Following Project Frame guidance, a time horizon from 2022–50 is set for Potential Impact projections. 2024–29 is used for Planned Impact, aligning with a commercial growth forecast horizon of five years. Realised Impact is a year-on-year analysis for the years 2022, 2023 and 2024.

Solution Scenario. For modelling purposes, the following solution scenarios were used (and year during which the analysis was conducted):

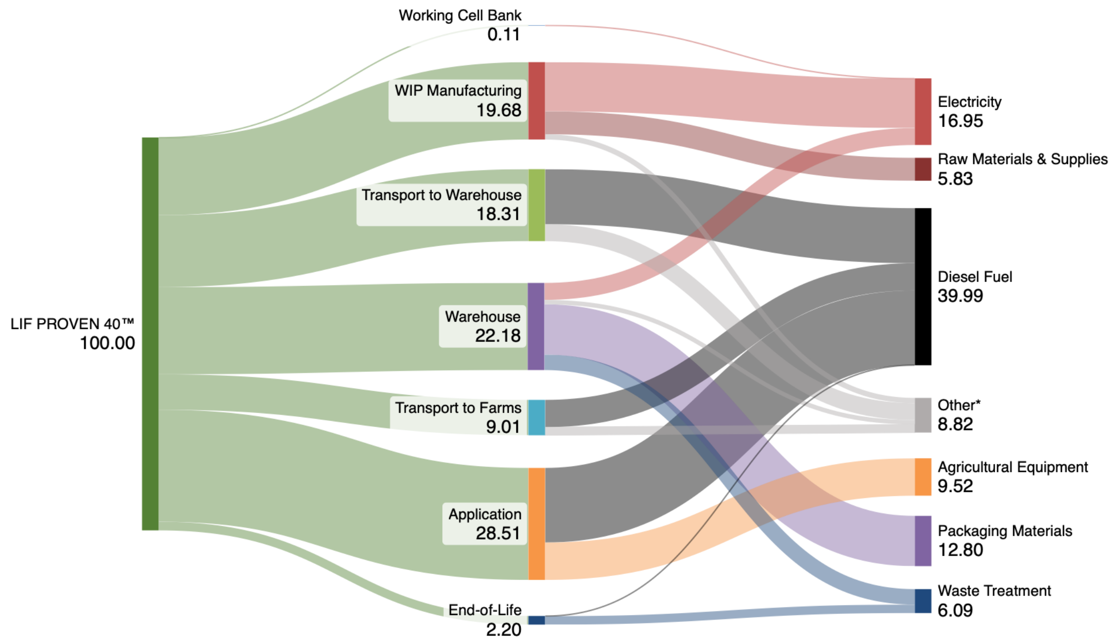
- Potential Impact (2022) - technical specifications of the product suggest 40lbs/acre Nitrogen replacement rate; Note model updated 2025 to reflect longer time horizons.
- Planned Impact (2024) - greater visibility into actual grower practices suggests a lower average application rate of 35lbs/acre, which is modelled to increase gradually over time as growers become more comfortable with using the product and choosing to replace greater amounts of synthetic N-fertiliser;
- Realised Impact (2025) - self-reported grower product application rates are used, excluding those under 20lbs/acre (an exclusionary threshold set by the company to reflect a minimum amount of N reduction considered statistically significant), which excluded 21% of 2024 grower data for which avoided emissions are not calculated or claimed.

Solution Emissions Factors. This represents a learning and maturation of assumptions over time, moving from a rough internal estimate (absent an LCA) to more product-specific LCAs:

- Potential Impact (2022) - pre-LCA, an internal process engineering estimate was developed and used (0.23kg CO_2eq/kg N).
- Planned Impact (2024) - a 2024 LCA (ISO 14044) was used with more refined assumptions and product and application-specific company data (0.54kg CO_2eq / acre).
- Realised Impact (2025) - an updated 2024 LCA (ISO 14044) further desegregated emissions by product application type (Liquid in Furrow -LIF or On-Seed, OS), 0.475 and 0.670kg CO_2e / acre, respectively). Note 0.54kg CO_2e used for continuity within the Nitrogen Credit programme (further discussed below).

Solution Emissions - Breakdown by Lifecycle Stage. The following example for Liquid-in-Furrow NFI solutions illustrates the relative contribution to overall emission by lifecycle stage:

Graphic 1: Sankey Diagram - LCA Analysis for LIF Proven40™



Source: 2024 LCA conducted by SCS Global Services;
* Includes maintenance of capital equipment, roads emissions, upstream processing and water treatment.

Reference Scenario(s). The avoided emissions assessments (Potential, Planned, Realised) are based on a 'partial replacement' model,* where nitrogen-fixation by microbes in NFI solutions reduce the need for synthetic nitrogen fertilisers in crop production. While current market adoption is limited (less than 14% of US growers reported using any type of NFI solution in 2023), scaling adoption could shift baseline nitrogen demand patterns, requiring periodic updates to reference scenarios to maintain relevance and accuracy. However, if NFI solution market share increases significantly, the reference scenario may need to be updated to reflect broader replacement dynamics (e.g., an average-based approach).

- Potential Impact - Ammonia is chosen as the reference fertiliser reduced as it is the least carbon intensive of the available options to growers and therefore reflects the most conservative choice. Given the long-term time horizon to 2050, this is modelled as a mix of conventional ammonia and green ammonia, weighted according to an increasing share of green ammonia over time in alignment with the IEA Ammonia Technology Roadmap (2021) SDS scenario forecast of 50% green ammonia production by 2050.

***Methodological choice - divergence from WBCSD guidelines**

WBCSD recommends comparing the solution scenario (including both NFI solutions and the remaining synthetic N-fertiliser applied post-reduction) to a reference scenario based on the prior three-year average of synthetic fertiliser use without NFI. While this approach does not change the net avoided emissions estimated, it does affect total emissions inventories at the grower level. In this example, the company reports only the Scope 1–3 emissions associated with manufacturing and use of its own NFI products, not total emissions from all nitrogen sources used by growers, which was considered out of scope.

- Planned Impact - Conventional ammonia is used as reference solution.
- Realised Impact - a market mix of synthetic N-fertiliser types reduced is used based on self-reported grower data in a given application season.

Emission Factors. Emissions factors are by their nature estimates. We choose to align as much as possible with IPCC AR6 2019 refinement to the 2006 Guidelines for National GHG inventories, disaggregating by dominant field characteristics wherever possible.

- Manufacturing Emissions
  - *NFI solution emissions factor*. Initial projections (Potential Impact) based on a 2022 internal process engineering emissions factor estimate, refined in July 2024 based on the ISO14044 Lifecycle Analysis conducted by SCS Global Services, and further updated in January 2025 (Planned and Realised Impact).
  - *Reference product emissions.* Initial Potential Impact projections were based on EPLCA PEF Open LCA emission factor for conventional ammonia (NH3) only (lowest reference GHG emissions factor among N-fertilisers), whereas Planned and Realised Impact calculations have greater specificity and reflect an updated set of synthetic N-fertiliser (conventional ammonia, UAN, urea, Nitric acid, Ammonium Nitrate, Ammonium Sulfate) manufacturing emissions factors from Argonne GREET R&D Model Feedstock Carbon Intensity Calculator. These emissions factors are reviewed annually and updated if there are changes.
- State-specific direct and indirect N_2O emission rates
  - *Potential Impact* - Direct and Indirect N_2O emissions were calculated using the Fast-GHG tool (Cornell Center for Sustainability (https://www.atkinson.cornell.edu/fast-ghg/), disaggregated by state, and converted to CO_2eq with a GWP of 273 (IPCC AR6). The GHG impact was then applied to all potential hectares using NFI Solutions in a given year (according to forecasted market penetration rates) and then summed.
  - *Planned and Realised Impact* - A more refined methodology was developed in 2024 to include the IPCC 2019 Refinement to the 2006 Guidelines for National GHG Inventories, including Tier 1 and Tier 2 regional emissions factors for Direct (EF1) and Indirect (EF4, EF5, FracGASF, FracLeach(-H)), aggregated and disaggregated according to:
    - Disaggregation by soil type follows Lawrence et al. 2021 https://www.pnas.org/doi/10.1073/pnas.2112108118
    - Disaggregation by humid class (aridity index >0.65) from Trabucco and Roberts (2019) dataset: https://doi.org/10.6084/m9.figshare.7504448.v5

Data Reliability for Realised Emissions. Realised emissions reductions are based on self-reported reductions in synthetic N-fertiliser use, comparing the current crop year to the previous crop year on a field-level basis. While self-reported data provides a practical and scalable foundation for estimating realised emissions, it is subject to limitations in consistency and precision, and should be interpreted with appropriate caution. To improve reliability, self-reported values are subject to validation where possible, and market averages are only derived after excluding statistical outliers to avoid distortion from anomalous responses. Emissions factors applied are specific to the stated replaced synthetic fertiliser mix, where available, or to the market average from the surveyed customer base when specific grower data not available. Analysis is focused on US cereal crops with stable nutrient management plans: thus, a one-year prior crop year baseline is used. A multi-year comparison (3–6 years) was considered in line with WBCSD recommendations, but did not yield significantly different results. This approach may require revision in markets with higher year-to-year variability. Realised impact data is generated from three primary data sets, listed in increasing order of confidence in the data accuracy:

- Customer Satisfaction surveys. Customer Satisfaction surveys are sent out three times per year: Post-Plant, Mid-Season and Post-Harvest. Each survey cohort is a distinct subset of the current season product customers, stratified for representation across geographies, farm size and customer tenure. The mid-season survey is streamlined and focused narrowly on satisfaction and product application issues; it does not contain nitrogen reduction questions. The post-plant and post-harvest surveys contain questions related to nitrogen reduction and participation in nitrogen credit ("N-Ovator") or agronomy support programmes. Because the marketing survey does not include field size, there may be some distortion in the data introduced here as % of managed acres is inferred from the % of respondents reporting a reduction across all of their managed acres. The stratification of the samples by farm size is a reasonable countermeasure to reduce data bias as much as possible given the constraints of the data collection method.
- Nitrogen credit programme (N-Ovator) participation data. When joining this opt-in programme, growers agree to provide additional field-specific data on nitrogen management practices. This data is used to calculate field-specific GHG reduction assets that are sold to downstream grain off-takers. Not every acre supplied is matched 1:1 with a demand-side buyer. This is because the demand is geographically constrained by supply sheds as defined by grain off-taker. In 2024, approximately 77% of supplied acres were matched with a downstream buyer. Eligibility to participate in this programme is reserved for growers whose fields meet the following eligibility requirements:
    - *Demonstrated reduction in synthetic N-fertiliser* evidenced with signed start-of-season agreement and end-of-season affidavit, with further internal quality control against sales and application use data.
    - *Exclusion of fields containing high carbon soils* (> 20% organic matter in the top 32 inches) as nitrogen interactions are less predictable in these cases.
    - *Field has been cultivated for at least 10 years* to ensure reported reductions are for nitrogen-stabilised fields and are truly attributable to fertiliser substitution, rather than underlying soil adjustments. This also confirms that there was no land-use change associated with participation in the nitrogen credit programme, in line with industry-standard safeguards to avoid land-use change emissions.
- Agronomy field visits for nitrogen assurance. Nitrogen assurance is an opt-in programme offered to new customers and large customers. Participating growers set up a grower standard practice check strip alongside the NFI treated crop. A company agronomist visits the field during the season and provides an analysis of nitrogen content using a proprietary field test (Reese-Nevins protocol) that combines chlorophyll analysis and plant fresh weight. The agronomist also collects the nitrogen application and reduction data for the field, including whether there was a reduction and, if so, what type of nitrogen was reduced.

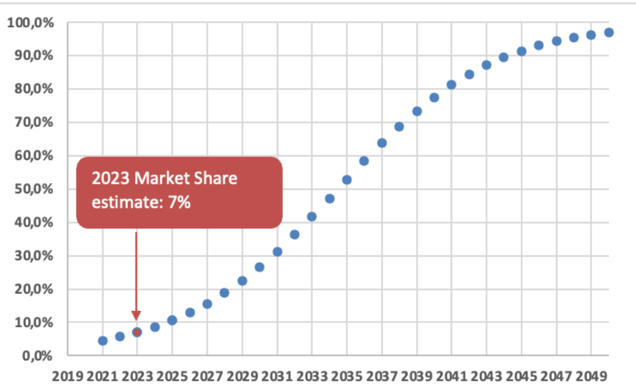
Attributional Approach. Given the global scale of synthetic N-fertiliser use, we do not estimate significant market effects on the supply or demand of synthetic fertiliser over the time period assessed for Potential (2050) or Planned Impact (5 years) as a result of growth in NFI solution use. Given the projected growth in new demand for ammonia, for example, it is uncertain if NFI solutions, currently priced at parity with lowest available cost synthetic N-fertilisers, will have an impact on pricing for the reference solution.

Minimum Replacement Threshold for Inclusion. Internal company agronomic review identifies 20lbs/acre of reduced synthetic N-fertiliser as representing a minimum threshold reduction rate of agronomic significance for direct and indirect emissions estimates. Therefore, only fields with self-reported nitrogen reduction amounts of 20lbs/acre or greater are considered in the analysis. Approximately 80% of growers in 2024 self-reported application rates greater than 20lbs/acre. This number is expected to continue to climb with grower education and product use experience.

US Corn Acres. US state-disaggregated corn acres totalling 89 million acres, assumed to be stable for the forward-looking Potential and Planned Impact analysis (in line with USDA projections through 2033).[9]

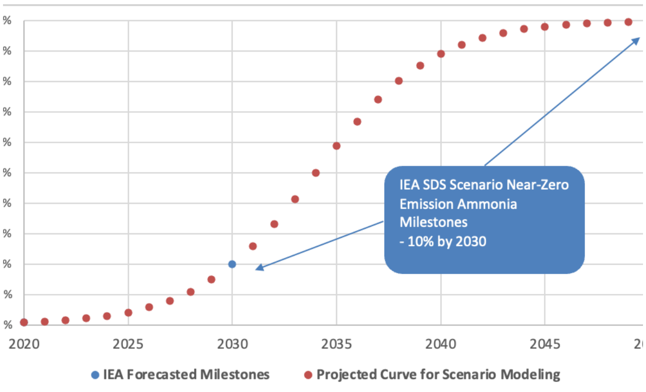
Market Adoption. A market-penetration S-curve (2019–50) was developed (see Graphic 2) for the Potential Impact Analysis and calibrated to a third-party estimate of market penetration rate of the company's NFI solutions reaching 7% of US corn growers by 2023.

Graphic 2: Projected Adoption (% growers applying 40lbs/acre) of NFI Solutions in US Corn Production (2019-2050)



Source: Stratus Ag Research (2023), Company Internal Modeling

Graphic 3: Percent (%) share of Near-Zero Emission vs. Conventional Ammonia production in alignment with IEA SDS Scenario



Source: EA Ammonia Technology Roadmap (2021), Internal Projections

Dynamic Reference Solution. Given the long-term time horizon of the Potential Impact analysis, it is reasonable to expect that lower-carbon alternatives to conventional synthetic nitrogen fertilisers — particularly green ammonia — will gain market share over time. To reflect this transition, we use a dynamic reference scenario for ammonia as the chosen reference solution, in which the replaced synthetic nitrogen fertiliser is modelled as a weighted average of conventionally produced ammonia (via the Haber-Bosch process) and near-zero emission ammonia (as defined by the IEA Ammonia Technology Roadmap (2021). This weighting shifts annually based on a projected market share curve for green ammonia (see Graphic 3). We select a scenario based on the IEA Sustainable Development Scenario, which anticipates that "zero-emission ammonia" (predominantly green ammonia) will account for 50% of global ammonia production by 2050. We model a logistic (S-curve) adoption trajectory for green ammonia from 2020 to 2050 (see chart), and use this to annually adjust a weighted emissions factor for ammonia applied to the reference ammonia baseline.

[9] USDA Agricultural Projections (2022): https://www.usda.gov/sites/default/files/documents/USDA-Agricultural-Projections-to-2033.pdf

Exclusions and Additional Considerations

- Changes in soil organic carbon or crop residue inputs. This methodology ties GHG emissions reductions specifically to decreases in nitrogen fertiliser use. Changes in soil organic carbon or crop residue inputs are not included, as they are assumed to be minimally affected by the intervention.
- Methodology considerations outside of developed markets. This assessment is specific to high-input US cereal systems. In emerging markets with lower synthetic nitrogen application rates and yields, these products may be used to drive yield improvements rather than fertiliser reductions. As NFI Solutions expand into new regions, further methodological considerations will need to be made to assess emissions impacts in cases where product use represents new nitrogen demand rather than a direct substitution.

Risks and Limitations

- Product/Technology Risk. This is the risk that NFI solutions do not deliver the intended nitrogen fixation, biomass or yield results. Pivot Bio supports and discloses extensive independent research and structured trials to validate their product promise, and regularly conducts and communicates annual field performance tests by State.
- Evidence Risk. Emissions factors for NFI solutions are based on the LCA-derived global warming impact per unit of finished product divided by application recommendations. Whether or not the grower applies the product in the recommended amounts and timing is a risk. A conservative methodology attempts to mitigate this risk within the N-Ovator programme by requiring a start-of-season grower agreement and end-of-season grower affidavit stating that the reported baseline synthetic N-fertiliser rate and synthetic N-fertiliser rate reduction is accurate and truthful. A further test is applied to validate that the state reduction of synthetic N-fertiliser applied to a given field corresponds to the purchase and application of Pivot Bio products within the growing season. Raw customer survey and agronomist-assisted responses are processed to exclude cases of limited stated nitrogen reduction. In 2024, this represented 21% of acres excluded from the analysis due to insufficient stated nitrogen reduction levels or insufficient data quality. A weighted average reference solution mix and average nitrogen reduction rates are inferred from the stratified survey data.
- Attribution Risk. There is a level of uncertainty in accurately attributing changes in N_2O emissions specifically to the replacement of synthetic N-fertilisers with NFI solutions. Various environmental factors, including soil type, microbial activity, moisture levels and baseline nitrogen mineralisation rates, can independently influence N_2O emissions. To mitigate this risk, wherever possible field types are disaggregated by corn belt zones (by State), climate zone type (Global Aridity Index),[10] and drainage class (SSURGO drainage class data categorized as 1–3 - Well Drained, 4–8 - Poorly Drained)[11] in order to apply more conservative and accurate emissions factors for each particular field. Furthermore, N-Ovator programme participation is limited to fields that have been cultivated for at least 10 years (to stabilise nitrogen cycling) and excluding high-carbon Histosol soils (>20% organic matter in the top 32 inches), where nitrogen interactions are less predictable.

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[10] Trabucco and Zomer (2019)

[11] SSURGO drainage class database (2023)

- Scientific Uncertainty Risk: Avoided emissions calculations are based on evolving scientific models and emissions factors, which may change as research advances the understanding of N_2O fluxes, soil interactions and biological nitrogen fixation efficiency. To address this uncertainty, the methodology uses conservative assumptions and includes a commitment to periodic recalibration as emissions factors evolve. An updated methodology is issued annually, reflecting the best available science for each reporting period.

Product Classification

- **UN Central Product Classification (CPC)**. Nitrogen-fixing biological inoculant solutions may be classified under CPC Subclass 34619 Other nitrogenous fertilisers and mixtures, n.e.c. These beneficial bacterial, while not chemical fertilisers, are a direct replacement for chemical fertilisers.
- **Global Industry Classification Standard (GICS)**: NFI solutions replace or complement synthetic fertilisers, classifying them therefore under sub-industry 15101030 Fertilisers & Agricultural Chemicals due to their analogous role in crop nutrition.

Forward-Looking Avoided Emissions Impact Analyses

Two examples of forward-looking avoided emissions impact analysis are presented here, Potential and Planned, representing two distinct use cases. The first is an early attempt at a speculative Potential Impact analysis that was performed in 2022 for internal use and in initial conversations between the investor and the company to qualify the potential magnitude of impact under a Total Available Market scenario, time bound to 2050 to reference the IEA SDS Scenario estimates for green ammonia market share development. The second is a Planned Impact Analysis that is grounded in a more nuanced understanding of forward-looking growth in use of the product by current and new customers, aligning with an internal, illustrative commercial growth plan over a five-year period (2024–29). This Planned Impact Analysis is used for internal target setting and as a performance benchmark for annual Realised Avoided Emissions calculations and disclosure.

Potential Impact

In this illustrative case, the potential scale of avoided emissions was initially estimated by Pivot Bio in 2022, using its internal process engineering–based lifecycle emissions estimate for the Proven40™ nitrogen-fixing solution. The scenario assumed full adoption across all cultivated US corn acres, replacing 40lbs/acre of synthetic nitrogen fertiliser — the product's recommended application rate. This early 'Total Addressable Market' (TAM) estimate was developed with support from Generation Investment Management and used during due diligence to illustrate potential impact in Pivot Bio's primary market: nitrogen delivery in US corn production. While the original analysis did not include a time dimension, it has been adapted for this case study to reflect a 2022–50 horizon, in alignment with Project Frame's recommended longer time horizons for assessing Potential Impact.

Focusing the forward-looking Potential Impact analysis on US Corn Acres over a 2022–50 time horizon requires a number of core assumptions described above and summarised here for context:

- Constant Nitrogen delivery rate from NFI solution microbes at 40lbs nitrogen per acre, with a proportional reduction in synthetic nitrogen fertiliser.
- Market share forecast for NFI solutions extending to 2050, calibrated to an external 2023 estimate of 7% market share.

- Dynamic reference solution scenario reflects a mix of conventional (Haber-Bosch) ammonia and near-zero emission ammonia, based on the IEA Sustainable Development Scenario (SDS) projections.
- Direct and indirect N_2O emissions were modelled using the FastGHG tool, disaggregated by US state and converted to CO_2e using a GWP of 273 (IPCC AR6).
- For solution emissions, a factor of 0.23 t CO_2e per tonne N was applied, based on internal process engineering estimates.
- Reference emissions for synthetic fertiliser manufacturing were conservatively based on ammonia replacement only, using a factor of 2.5897 t CO_2e per tonne N (sourced from EPLCA PEF Open LCA).
- Future green ammonia emissions factors were drawn from the Hydrogen Council & LBST (2021) report: Hydrogen Decarbonisation Pathways: Part 1 – Life-Cycle Assessment of Hydrogen Production and Use, which projects a value of 0.187 t CO_2e per t NH_3 (or 0.227 t CO_2e per t N) by 2030. This value aligns closely with the solution emissions factor used for NFI solutions.
- Finally, the total GHG impact was aggregated across all potential hectares by state, incorporating the dynamic market adoption of NFI solutions, the evolving ammonia emissions mix, and direct and indirect N_2O emissions factors.

Potential Impact Estimation. This results in a projected potential impact of over 10,3 million t CO_2e avoided emissions annually by 2050, under the speculative assumptions of a market share S-curve reaching 100% by 2050, where the technology solution is adopted across nearly all 100% of US corn acres at a replacement rate of 40lbs/acre of synthetic Nitrogen (44.83kg/hectare) with nitrogen-fixing biological inoculant (NFI) solutions. In a more near-term view, this potential impact analysis speculates a potential total annual avoided emissions amount of 1.07 million t CO_2e in 2024, rising to 3.2 million t CO_2e annually by 2030. It is important to note that this analysis did not include cumulative potential figures, as recommended by Project Frame. Instead, these internal annual avoided emissions projections were used to ease comparison with Planned Impact estimates.

See XLS - Potential Impact

***Updating methodology and assumptions over time**

An initial Potential Impact Analysis was included in the 2022 Impact Report, but subsequently not published in recent impact reports as the company developed a more robust methodology for its Planned and Realised emissions assessments. It was based on an initial estimate of manufacturing, direct and indirect avoided emissions for the most conservative potential synthetic nitrogen fertiliser replacement of conventional ammonia. It also preceded the third-party LCA (2024) and a more robust methodology of using IPCC 1 and IPCC 2 desegregated emissions factors for direct and indirect emissions and Argonne GREET R&D reference emissions by N-fertiliser type. It is included here to demonstrate a practical example of an initial methodological approach to forward-looking emissions calculations that was replaced with a more nuanced Planned Impact assessment methodology.

Planned Impact

This section presents the forward-looking, Planned Impact estimation based on illustrative commercial growth and annual customer end-use projections for a Pivot Bio NFI solution (Proven40™) over a five-year period (2024–29).

Insights from the early years of product commercialisation show that avoided emissions impact does not scale directly with new product sales. Instead, impact depends on several interrelated factors during each growing season: the number of acres treated, the solution application rate (lbs/acre), and the corresponding amount of synthetic nitrogen replaced per acre, with particular focus on those growers who choose to replace more than 20lbs/acre of synthetic N-fertiliser with NFI solutions on their crops. These factors collectively are important factors in determining the total avoided emissions achieved each season.

To reflect these dynamics, we model an illustrative five-year planned impact analysis focused on the total potential nitrogen replaced annually, using the following variables that drive increased synthetic nitrogen replacement:

- Acre Expansion: The growth rate in the total number of acres using NFI solutions (primarily through new grower adoption).
- Nitrogen Replacement Rate per Acre: The growth rate in the average amount of synthetic nitrogen replaced per acre (driven by education and grower outreach).
- Percentage of Growers applying above exclusion threshold: We limit the impact assessment to only include those acres with replacement rates over 20lbs/acre, in line with agronomist estimates of statistical significance, and to reflect grower education efforts over time.

Forecasting Assumptions

Planned impact forecasting assumptions are more nuanced than the original potential impact assumption of 40lbs/acre of reduced Nitrogen across all eligible acres. Here, we model the estimated growth of product-specific acres (Proven40™), using a dynamic average application rate (lbs/acre), and an increasing % of growers indicating reduction of synthetic Nitrogen use and associated replacement with a Pivot Bio NFI solution. We also use a third-party LCA emissions data for the NFI solution, where the LCA is based on the functional unit of one package of Pivot Bio microbes, and those microbes are then applied to the seed to colonise and deliver an expected amount of nitrogen.

- 2024 Base Case - Average grower replacement rate of 35lbs/acre, product application rates and total customer base acreage from the latest growing season for Proven40™, resulting in a base case amount of 88.2 million lbs nitrogen fertiliser replaced:
    - *Calculation*: % growers replacing x Replacement Rate (lbs/acre N) x # acres = total projected lbs N replaced: 70% of growers (customers) replacing 35lbs/acre (N) with Proven40™ on 3.6 million acres = 88.2 million lbs N replaced;
- Five-year projections - here we model an illustrative five-year commercial growth strategy with a range of growth considerations for each of the three main variables that drive overall nitrogen replacement rates:
    - *Low Case* - 2% CAGR for each variable
    - *Medium Case* - 4% CAGR for each variable
    - *High Case* - 6% CAGR for each variable

This yields the following range of estimated N replaced in 2029 (in five years) under the three scenarios:

- Low Case (2% CAGR) - 77.3% growers x 38.6lbs/acre x 4.0 million acres = 118.7 million lbs N replaced in 2029.
- Med Case (4% CAGR) - 85.2% growers x 42.6lbs/acre x 4.4 million acres = 158.8 million lbs N replaced in 2029.
- High Case (6% CAGR) - 93.7% growers x 46.8lbs/acre x 4.8 million acres = 211.4 million lbs N replaced in 2029.

From the estimated range of lbs of nitrogen replaced (118.7 to 211.4 million lbs N), we use the most conservative assumption of 2.88 tCO_2eq / t N-fert (NH_3) for reference scenario manufacturing emissions. Another methodological choice could be to use a hypothetical market mix of synthetic N-fertilisers, but this adds additional uncertainty and risks overstating the impact, and so the most conservative (lowest) GHG emission factor for synthetic nitrogen, conventional ammonia (NH_3) is selected. For solution manufacturing emissions, we use the July 2024 LCA figure of 0.54kg CO_2eq/acre. For Direct and Indirect emissions, we choose not to model distribution of acreage by soil type, climate type and location given the number of assumptions that would need to be made and corresponding uncertainty. Instead, we base the analysis on aggregated emissions factors from IPCC AR6. We use 0.010kg N_2O-N/kg N for direct emissions from managed soils and aggregated indirect emissions factors of EF4 (0.010), FracGasf (0.11), EF5 (0.011) and FracLeach-(H) (0.24). Indirect emissions are calculated as EF4xFracGASF + EF5xFracLEACH-(H) = 0.00374 kg N_2O-N/kg N for indirect emissions. This yields:

- Manufacturing emissions - Reference emissions are 2.88 t CO_2eq/t N-fert. Solution Emissions are (0.54 t CO_2eq/acre).
- Direct emissions from managed soils are estimated using the aggregated emission factor of 0.010 kg N_2O-N per kg N, the N_2O-N to N_2O conversion factor of 1.57, and the GWP(2021) of 273, we calculate direct emissions as: (0.010 x 1.57) x 273 = 4.289 kg CO_2e per kg N or 4.289 t CO_2e per t N.
- Indirect emissions from managed soils are estimated using the aggregated emission factor of 0.00374 kg N_2O-N per kg N, the N_2O-N to N_2O conversion factor of 1.57, and the GWP of 273, we calculate indirect emissions as: (0.00374 x 1.57) x 273 = 1.60 kg CO_2e per kg N or 1.60 t CO_2e per t N.

Therefore, the resulting projections for year five annual planned impact (2029) range from:

- LOW: 470,713 tCO_2eq (118.7 million lbs N in year five, with 4 million acres, 77.3% growers replacing an average of 38.6lbs N/acre.
- MED: 630,109 tCO_2eq (158.8 million lbs N in year five, with 4.4 million acres, 85.2% growers replacing an average of 42.6lbs N/acre.
- HIGH: 838,745 tCO_2eq (211.4 million lbs N in year five, with 4.8 million acres, 93.7% growers replacing an average of 46.8lbs N/acre.

Backward-Looking Avoided Emissions Impact Analysis

Realised Impact

This 2024 Realised Impact assessment demonstrates the application of additional methodological choices and field-level data collection practices to support estimated avoided emissions calculations.

Realised Impact is calculated using the company's 2024 GHG Calculation Methodology v1.0, a documented process reviewed and updated annually. The company evaluates whether changes in emission factors or other assumptions significantly affect the reported avoided emissions. If so, revised annual and cumulative impact figures are issued.

Annual impact data comes from three primary data sets collected through existing 'know-your-customer' channels (further described above in nitrogen reduction data sources):

- Nitrogen Credit programme - participant data (36% of 2024 data). Field-specific baseline synthetic N-fertiliser use is determined using the per acre synthetic N-fertiliser application rate of the most recent crop-year cultivated without company microbial products. Synthetic N-fertiliser reductions per acre are then calculated using grower data on synthetic N-fertiliser type, rate and application. Upon signing of the end-of-season affidavit, these data are evaluated against the programme participation criteria for eligibility. Field-specific number of acres, nitrogen reduction data and weighted nitrogen replacement manufacturing emissions factor are used to calculate field-level GHG avoided emissions, which are aggregated by state to contribute to overall emissions reductions calculations.
    - an average N reduction rate of 33.3lbs N / acre (N-Ovator programme participants only)
- Nitrogen Assurance programme - agronomy data (1% of 2024 data). For participants in the Assurance Programme, company agronomists collect field-specific data, including baseline synthetic N-fertiliser use, the amount reduced, and the type of nitrogen reduced (as a percentage mix of N-fertiliser types). Based on this data, the average nitrogen reduction rate among programme participants is 31.7lbs N per acre. A weighted average manufacturing emissions factor is used from the customer experience survey results.
- Customer Experience Survey Participants (63% of 2024 data). For those growers who are not in the nitrogen credit programme nor working directly with the commercial agronomist, pre-planting and post-harvest customer experience survey data is used to estimate the per acre synthetic N-reduction amount and breakdown of reduction across reference synthetic fertilisers reduced. Respondents who replace than 20lbs/acre are excluded, as are participants in the nitrogen credit and Assurance programmes. Where multiple synthetic fertiliser mixes are reported as reduced, the more conservative product from an emissions standpoint is assumed. Field characteristics (soil type, humidity level) are not surveyed and are assumed to align with the most common classification type for each state in which the field is located. The following averages are estimated from this 2024 survey data:
    - an average N reduction rate of 31.7lbs N / acre
    - An average mix of N-fertiliser reduced of 35% NH_3, 39% UAN and 26% UAN, with a corresponding weighed average manufacturing emissions factor of 3,78 $tC0_2e$ / t N.

Process Steps for Calculating Realised Emissions:

For each set of impact data, by state, we estimate field-level GHG emissions avoided (ΔGHG; in tons of CO_2 equivalents), using the following formula: $\Delta GHG = \Delta GHG\ M + \Delta GHG\ N_2O$.

Manufacturing Emissions (ΔGHG M):

- Identify synthetic nitrogen reduction amounts: from Nitrogen Credit Programme baseline and non-programme self-reported estimates.

- Multiply the synthetic nitrogen reduction amount by the relevant product type manufacturing emissions factor (or weighted average in the case of non-programme estimates) (see Table 4). Important note, nitrogen credit programme participant avoided emissions were calculated earlier in the reporting year using the July 2024 LCA figure (0.54 kg CO_2eq/acre) which serves as the basis for 2024 partnership agreements. An updated January 2025 LCA further distinguishes emissions factors by product application type (LIF, OS) at 0.475 and 0.670 kg CO_2eq/acre). However, given the very low overall emissions from the NFI solution, a practical choice was made not to recalculate the LCA. emissions factor for nitrogen credit programme participants in the current year.
- Calculate NFI solution emissions based on application area by the LCA-derived product emissions factor (0.54kg CO_2eq/acre for N-Ovator programme acres and 0.475 and 0.670 for Proven40LIF and Proven40OS non-programme and agronomist-visited acres).
- Subtract NFI solution emissions from synthetic nitrogen emissions to estimate net manufacturing emissions reduction.

Table 4: Manufacturing Emissions Factors for Realised Impact Assessment

MANUFACTURING EMISSIONS FACTORS		
Nitrogen Source	**Unit of Measure**	**Emission Factor (EF)**
Proven40 LIF* N-Ovator	kg CO_2e / acre†	0.54
Proven40 OS* N-Ovator	kg CO_2e / acre†	0.54
Proven40 LIF*** non-programme & agronomy	kg CO_2e / acre†	0.475
Proven40 OS*** non-programme & agronomy	kg CO_2e / acre†	0.670
Conventional ammonia ‡	tonne GHG / tonne N-fert §	2.88
UAN ‡	tonne GHG / tonne N-UAN	4.56
Urea ‡	tonne GHG / tonne N-urea §§	3.84
Nitrid acid ‡	tonne GHG / tonne N-fert ^^	9.18
Ammonium Nitrate ‡	tonne GHG / tonne N-fert **	6.36
Ammonium Sulfate ‡	tonne GHG / tonne N-fert ^	3.29

* ISO 14044 Lifecycle Analysis conducted by SCS Global Services, July 2024 (N-Ovator Acres), January 2025 (Non-program & agronomy acres)
‡ Argonne GREET R&D Model (anl.gov), 2023 v1. Converted from US short ton to metric tonne
† LCA derived global warming impact per unit of finished product divided by application recommendations
§ Converted from ton final fertiliser by dividing by nitrogen content (82%, or 0.82)
§§ Includes process emissions; converted from ton final fertiliser by dividing by nitrogen content (46%, or 0.46)
^^ Converted from ton final fertiliser by dividing by nitrogen content (22%, or 0.22)
** Converted from ton final fertiliser by dividing by nitrogen content (35%, or 0.35)
^ Converted from ton final fertiliser by dividing by nitrogen content (21%, or 0.21)

Direct and Indirect N_2O Emissions (ΔGHG N2O): The IPCC AR6 (2019) provides direct and indirect Tier 1 N2O emissions factors (EFs) disaggregated by climate zone. These are standardised, globally applicable emissions factors based on broad averages are recommended when country- or region-specific data are not available. Tier 2 emissions factors are customised to specific regions, systems or practices. In the case of the US and corn, Tier 2 regional emissions factors exist for production in corn belt states with high-productivity, high nitrogen fertiliser use croplands. These are important for modelling as N_2O emissions from fertiliser use vary greatly depending on the drainage class (well-drained vs. poor drainage) and aridity (wet climate or dry climate).

Tier 1 default EFs are combined with Tier 2 regional EFs as defined in the peer-reviewed literature. We refer to a 2021 peer-reviewed study (Lawrence et al, 2021) that identifies emissions factors for corn systems in the US corn belt based on soil drainage class. Given this, a more specific methodological approach of calculating direct and indirect N_2O emissions using disaggregated emissions factors is applied, depending on the data availability within each reference data set (Nitrogen Credit, Nitrogen Assurance or Customer Experience).

- N_2O Direct Field Emissions – Corn
    - *All acres: Identify the synthetic N-reduction* (N-Ovator baseline or non-programme self-reported estimate).
    - *N-OVATOR only*: Corn Belt states (IL, IN, IA, KS, MI, MN, MS, NE, ND, OH, SD, WI): IPCC Tier 2 regional emissions factor specific to the high-productivity, high nitrogen fertiliser use croplands of the US corn belt is applied for direct field emissions derived from Lawrence et al (2021).
        - Segment fields in Corn Belt according to their average soil drainage class (SDC), as indicated in the USDA SSURGO database (field name: Drainage Class - Dominant Condition).
        - Multiply the synthetic nitrogen reduction by the appropriate direct emissions factor (EF1) based on drainage class (well drained or poorly drained) to estimate direct field emissions – see Table 3
    - *All other locations and non-programme acres*: Use IPCC Tier 1 disaggregated emissions factors.
        - Determine IPCC climate zone wet or dry using Global Aridity Index and Potential Evapotranspiration Database Version 3.0.
        - Multiply the synthetic nitrogen reduction by the appropriate wet or dry direct emissions factor (EF1) to estimate direct field emissions – see Table 3.
- N2O Direct Field Emissions – all other crops
    - *Identify the synthetic nitrogen reduction* (N-Ovator baseline or non-programme self-reported estimate)
    - *Use IPCC Tier 1* disaggregated emissions factors.
        - Determine IPCC climate zone wet or dry using Global Aridity Index and Potential Evapotranspiration Database Version 3.0.
        - Multiply the synthetic nitrogen reduction by the appropriate wet or dry direct emissions factor (EF1) to estimate direct field emissions – see Table 3.
- N2O Indirect Field Emissions – All Acres, All Crops
    - *Identify the synthetic nitrogen reduction* (N-Ovator baseline or non-programme self-reported estimate).
    - *Use IPCC Tier 1* disaggregated emissions factors.

- Determine IPCC climate zone wet or dry using Global Aridity Index and Potential Evapotranspiration Database Version 3.0.
- N_2O Indirect Field Emissions: Multiply the synthetic nitrogen reduction by the appropriate wet or dry indirect emissions factor (EF4) and multiply by FracGASF to estimate indirect field emissions – see Table 3.
- N_2O Indirect emissions from N leachate in locations where leaching occurs: Multiply the synthetic nitrogen reduction by appropriate wet or dry FracLEACH – (H) to estimate N loss as leachate. Multiply N loss as leachate by EF5 to estimate N_2O indirect emissions from N leachate – see Table 3.

- Convert N_2O-N into CO_2e
  - *Convert* N_2O-N into N_2O (Multiply by molar weight of N_2O, 44/28).
  - Convert N_2O into CO_2e (Multiply by global warming potential (GWP) of N_2O, as per IPCC AR6, 273x)

Table 5: Direct and Indirect Field Emissions (N_2O)

REFERENCE SOLUTION - DIRECT AND INDIRECT N_20 EMISSIONS FACTORS									
			EMISSIONS FACTORS						
Corn Belt States*	SSURGO Drainage class	Climate Zone Type	Direct §	Indirect §§ (EF4xFracGASF + EF5xFracLeach-(H))					Total
			EF1	EF4	FracGASF	EF5	FracLeach-(H)		EF#
Yes	1 to 3 (Well-drained) †	Wet ‡	0.017	0.014	0.11	0.011	0.24		0.02118
		Dry	0.017	0.005	0.11	0.011	0		0.01755
	4 to 8 (Poorly-drained) †	Wet	0.038	0.014	0.11	0.011	0.24		0.04218
		Dry	0.038	0.005	0.11	0.011	0		0.03855
No	Any	Wet	0.016	0.014	0.11	0.011	0.24		0.02018
		Dry	0.005	0.005	0.11	0.011	0		0.00555

* Includes: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota & Wisconsin

† Disaggregation by soil type following Lawrence et al. 2021 https://www.pnas.org/doi/10.1073/pnas.2112108118
‡ Humid class (aridity index > 0.65) from Trabucco and Roberts (2019) dataset: https://doi.org/10.6084/m9.figshare.7504448.v5
§ Table 11.1 IPCC methodology
§§ Table 11.3 IPCC methodology
\# Reported as kg N-N_2O per kg of N fertiliser applied

For each of the three nitrogen reduction nitrogen data sources (N-Ovator, Agronomy, Customer Survey), we apply the above relevant manufacturing emissions factors for NFI solution and reference products (type of synthetic N-fertiliser used) and relevant emissions direct and indirect field emissions factors (disaggregated where possible by location, soil type, climate zone, drainage class) according to the IPCC AR6 (2019) methodology.

ΔGHGYEAR = ΔGHGfield 1… + ΔGHGfield 2 … ΔGHGfield n

We then aggregate all field and state-level emission reduction estimates for a given growing season, with the following estimated annual realised avoided emissions impact claims:

- **In 2024, growers avoided 567,035 metric tons CO_2e emissions**, of which 242,000 metric tons CO_2e (42.7%) were sold under the Nitrogen Credit programme
- **In 2023, growers avoided 512,000 metric tons CO_2e emissions**, of which 110,000 metric tons CO_2e (21%) were sold under the Nitrogen Credit program
- **In 2022, growers avoided 226,600 metric tons CO_2e emissions**, with no sold credits

In line with WBCSD recommendations, avoided emissions claims are reported separately from Scope 1–3 emissions in the annual impact report. Realised avoided emissions claims are disclosed alongside the volume of nitrogen credits sold to ensure clarity on attribution and prevent double-counting.

Data Sources / Additional Information

Manufacturing emissions. Full lifecycle manufacturing emissions for Pivot Bio products (Proven40™ and Return™) and reference products (conventional ammonia, UAN, Urea, Nitric Acid, Ammonium Nitrate and Ammonium Sulfate) are derived from:

- Internal process engineering estimates (for 2022 Potential Impact projections only)
- ISO 14044 Lifecycle Analysis conducted by SCS Global Services, July 2024 and updated January 2025
- Argonne GREET R&D Model (anl.gov), 2023 v1, Feedstock Carbon Intensity Calculator (FD-CIC Tool 2023), released 30 April, 2024
- EPLCA PEF Open LCA (for 2022 Potential Impact projections only).

Field emissions. Direct and indirect field emissions are derived from and disaggregated, based on a number of sources, including:

- FastGHG tool, Cornell Atkinson Center for Sustainability, https://d-woolf.shinyapps.io/FAST-GHG/ (accessed 2022 for Potential Impact projections)
- IPCC. 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories. "Chapter 11: N2O Emissions from Managed Soils and CO_2 Emissions from Lime and Urea Application." https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf
- Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at https://websoilsurvey.nrcs.usda.gov/. Disaggregation by drainage class and climate zone type is inferred based on the state location of the field.
- Lawrence, N. C., Tenesaca, C. G., VanLoocke, A., and Hall, S. J. (2021). "Nitrous oxide emissions from agricultural soils challenge climate sustainability in the US corn belt." Proceedings of the National Academy of Sciences, 118(46). https://doi.org/10.1073/pnas.2112108118
- Trabucco, Antonio; Zomer, Robert (2019). Global Aridity Index and Potential Evapotranspiration (ET0) Database: Version 3. figshare. Dataset. https://doi.org/10.6084/m9.figshare.7504448.v5

- Numerous and ongoing university field trials, state-level seasonal performance reports, peer-reviewed science and independent research studies by over 22 land-grant institutions (https://www.pivotbio.com/research-reports)

Customer Data. Customer reported solution use and synthetic N-fertiliser replacement rates are captured using three methods (described above).

Analysis & Commentary

Analysis Summary

Calculating both the forward-looking GHG impact analysis and realised year-over-year analysis requires a number of assumptions and the practical constraints of data availability and quality. For forward-looking projections, we choose not to model the potential mix of N-fertiliser types reduced (with high emission factor variability), and choose instead to limit forecasts to replacement of the lowest-GHG impact N-fertiliser only, conventional ammonia. There is also significant variability in direct and indirect field use emissions factors once disaggregated data is applied. We endeavour to bring this level of complexity into Realised Impact calculations, but default to aggregated emissions factors for forward-looking projections.

Step-by-Step Model Construction

1. Qualify Impact. We start from the well-documented assertion that Pivot Bio NFI solutions, Proven40™ and Return™, offer a viable nitrogen-fixing alternative to synthetic N-fertiliser that maintains or improves yields. The impact results from a reduced use of synthetic N-fertiliser and associated manufacturing, direct and indirect emissions. We define the system boundaries as nitrogen fixation solutions for cereal crops in the US, including manufacturing and in-field application. We use LCA-defined functional units for the solution, 1 finished package of product microbes, with packaging, applied to farmland, both in per package and per acre units. This is then converted to a 'comparable functional unit' based on the assumption of a product application rate of 40lbs/acre, to derive Kg Nitrogen (Biologically Fixed) per Acre. For the reference solution partially substituted, we use LCA-defined functional unit of Kg Nitrogen (Haber-Bosch) replaced, and convert to a Kg Nitrogen (Haber-Bosch) Replaced per Acre.

Choice of Functional Unit

WBCSD suggests best practice to define the functional unit around end-product or final application (e.g., volume/weight corn). However, an input-related functional unit (kg nitrogen reduced per acre) was used in this case to simplify calculations given the complexity of emissions factors, limited data and time. In this instance, ICF attempted to follow Project Frame's recommendation on defining and quantifying units, "choosing simpler calculations when all else is equal, for the sake of quality control, efficiency, and transparency." An analysis based on output-based units could improve comparability across solutions and robustness of the analysis, and is an important area for future consideration.

We express impact in kg CO_2e avoided realised annually (2022, 2023, 2024) and over a forward-looking, five-year (2024–29) period for Planned Impact and a long-term (2022–50) time horizon for Potential Impact.

2. Construct Baseline Scenario. We define the baseline (reference) scenario, at the field level, as the synthetic N-fertiliser application amount reduced in the current crop growing season as compared to the previous crop growing season (N-Ovator baseline or non-programme self-reported estimates). This includes an estimate of the breakdown of synthetic N-fertiliser reduced by fertiliser type (conventional ammonia, UAN, urea, nitric acid, ammonium nitrate or ammonium sulfate). We define the solution scenario as the amount of Pivot Bio nitrogen application amount per acre (N-Ovator baseline or non-programme self-reported estimates). Through internal agronomic review of product performance and nitrogen application rates, 20lbs was identified as an agronomically significant threshold under which the contribution of N from the microbes would be complementary to the synthetic N applied to the crop and therefore not distinguishable. Therefore, application rates below 20lbs/acre are excluded from the assessment. We validate that the solution scenario is a replacement for existing demand by asking growers in their self-reported estimates.

3. Obtain Emissions Factors. We obtained a third-party LCA from SCS Global Services in 2024 and use those findings for the solution emissions factor. We rely on Argonne GREET emissions factors in the US for manufacturing emissions from reference synthetic N-fertilisers. These are assumed constant over time as they have been historically stable, but annual methodological review includes updating these with dynamic emissions factors if warranted. For direct and indirect emissions estimates, we rely on IPCC Tier 1 and Tier 2 regional emissions factors (kg N_2O-N/kg N input), including EF1 (direct emissions), EF4 (indirect volatilisation/deposition emissions), FracGASF (fraction of synthetic fertiliser N applied to soils that volatilises as NH_3 and NO_x), EF5 (indirect leaching/runoff emissions), and FracLeach-(H) (indirect N losses by leaching/runoff in wet climates). We further disaggregate emissions factors by location (high-productivity, high-nitrogen fertiliser use in Corn Belt states), drainage class (USDA SSURGO) and climate zone type (wet/dry) in accordance with Lawrence et al (2021) and Trabucco and Roberts (2019).

4. Calculate Unit Impact. At the field level, we use the following equation: $\Delta GHG = \Delta GHG\_M + \Delta GHG\_N_2O$, as described in detail above.

Specificity Level - HIGH. In line with WBCSD recommendations, we assess the specificity level of the avoided emissions claim as HIGH (for the published Realised Emissions estimates):

- <u>Solution (S) - Medium</u> - we use a company and product-specific LCA to determine average lifecycle emissions of the solution across field types (COMPANY-SPECIFIC)
- <u>Reference (R) - High</u> - we use field-level data specific to the customer's intended and stated reduction of synthetic N-fertiliser by type (CUSTOMER-SPECIFIC), including location, soil drainage class and climate zone type.

Attribution/Allocation. As a direct product used by growers in the production of cereal crops, we assert that the avoided emissions reductions are a result of replacing synthetic N-fertiliser with Pivot Bio solutions. This is supported by independent research and field trials. Therefore in avoided emissions reporting we allocate 100% of the avoided emissions reduction to the product use. This attribution allocation could be revisited as more guidance and market standards on value chain attribution become available.

Eligibility Gates

The WBCSD establishes the following eligibility gates in its guidance on Avoided Emissions calculations. This illustrative case concerns a growth-stage company with a relatively low operating footprint.

Gate 1: Climate Action Credibility. *The company has set and externally communicated a climate strategy consistent with the latest climate science, providing robust GHG footprint measurement and including science-based informed targets covering Scope 1, 2 and 3, transparently reporting on progress on a regular basis.*

We note that the company discloses its Scope 1, 2 and 3 emissions in its annual impact report. This is based on a full LCA and calculated using Persefoni.

Table 6: Scope 1–3 Emissions

Company -reported Scope 1–3 Emissions	2023	2024
Scope 1	1,031 tCO_2e	720 tCO_2e
Scope 2	631 tCO_2e	844 tCO_2e
Scope 3	24,490 tCO_2e	19,597 tCO_2e

Source: Company 2024 Disclosure, forthcoming 2024 Impact Report

The Impact Convergence Forum members acknowledge WBCSD draft guidance allowing for a case-by-base assessment of climate action credibility for those companies not yet able to demonstrate validated climate targets. Here, we note that the company has not yet established validated targets against a climate framework (e.g., SBTi) given the costs associated with doing so and the nature of its business with 100% of its products and revenues aligned with sustainable agriculture practices.

While the company has not yet established a Science-Based Target initiative (SBTi) validation, its core business model is inherently aligned with 1.5°C pathways, contributing directly to Scope 3 emissions. reductions for its customers. In line with WBCSD's draft guidance, the company provides transparent, verifiable evidence of its climate impact, with its technology demonstrably reducing GHG emissions at scale. As the company matures, engagement with third-party verification processes and further alignment with IPCC and IEA decarbonisation pathways will further substantiate its climate action credibility.

Gate 2: Climate Science Alignment. *The solution (or end-solution of the intermediary solution) has mitigation potential according to the latest climate science and recognised sources, and is not directly applied to activities involving exploration, extraction, mining and/or production, distribution and sales of fossil fuels, i.e., oil, natural gas and coal.*

The company's products directly address a decarbonisation challenge within the agricultural sector, specifically reducing nitrous oxide (N_2O) emissions and synthetic N-fertiliser reliance, which are significant contributors to global greenhouse gas emissions. According to the IPCC AR6, N_2O emissions from agriculture account for approximately 67% of global anthropogenic N_2O emissions, primarily driven by fertiliser application and soil microbial activity. Furthermore, the International Energy Agency (IEA) has identified low-emission agricultural innovations as critical to achieving net-zero emissions by 2050, highlighting the need for scalable solutions that reduce reliance on fossil fuel-derived inputs.

Gate 3: Contribution Legitimacy. *The solution has a direct and significant decarbonising impact (Direct Product, Direct Component)*

Pivot Bio solutions demonstrate contribution legitimacy according to WBCSD guidelines:

- Decarbonising. Pivot Bio NFI solutions enable reduced GHG emissions compared to the reference scenario of no reduction in synthetic fertiliser use for a given field. This is quantifiable using established IPCC emissions factors for reference scenarios both in manufacturing emissions and on-field application emissions.

- Direct. The nitrogen-fixation properties in Pivot Bio NFI solutions directly reduce the need for equivalent nitrogen amounts from synthetic fertiliser. This reduction is evidenceable and traceable, supported by independent research, customer surveys and seasonal disclosure agreements.
- Significant. While annual nitrogen application rates vary, recommended rates are typically between 140–200lbs/acre for high-yield crops. Replacing 40lbs/acre with Pivot Bio NFI solutions represents 20–30% of total nitrogen applied, a substantial shift. Furthermore, scientific studies indicate that direct and indirect N_2O emissions reductions become significant at application rates above 20lbs/acre of Pivot Bio microbial nitrogen.

Challenge & Side Effects

Challenges

Building Customer Confidence in a Novel Solution – The avoided emissions impact of NFI relies on grower practice change, replacing a long-standing reference solution with something entirely new. Adoption takes time as growers build trust — not just in the product itself, but in the broader concept of nitrogen replacement. Over the years, we've seen steady, incremental increases in the percentage of growers making this shift.

Validation of Self-Reported Data – The avoided emissions assessment relies on grower-reported reductions in synthetic nitrogen use, which may introduce variability and reporting inconsistencies. Validation of all self-reported data at the field level is time-consuming and cost prohibitive. However, we address this challenge through a number of grower programmes. The first, N-Ovator, is an insetting mechanism, similar to carbon credits, linking market incentives with grower practice change to create additional value for both Pivot Bio's product and its grower customers. In this programme, growers disclose synthetic N-fertiliser reduction intent at start-of-season, and confirm synthetic N-fertiliser reduction amounts in an end-of-season affidavit. This data additionally passes quality control against known sales and recommended application usage rates. While not originally developed to improve data accuracy, the programme's structure generates high-quality data as a secondary benefit. A second programme sends commercial agronomists on-site to complete a Nitrogen Survey, providing an additional level of confidence in the grower-reported data. Remaining estimates of reduced synthetic Nitrogen fertiliser use associated with Pivot Bio product use are collected through a Customer Experience survey. Here, while we are not able to validate field-level reported data, we use the weighted average of stated synthetic N-fertiliser reduction (by type) and assign disaggregation tags (climate, drainage class) by state location.

There are increasing opportunities for growers to engage in incentive programmes beyond N-Ovator, such as the ADM re:generations programme, which incentivises a suite of regenerative practices and measures performance and outcomes through external MMRV platforms like Gradable. These programmes are complementary and may offer better options for growers adopting a broader range of regenerative, low-carbon practices. As Pivot Bio solutions scale, such programmes may prove more efficient than N-Ovator in aligning market demand for sustainable production with grower practices related to nitrogen management, cover cropping and tillage. While this expansion is beneficial for driving demand and accelerating adoption, it may also lead to reduced visibility into field-level data in the future.

Side Effects

Overall Environmental Impact Relative to Synthetic N-Fertilisers. Cradle-to-grave Lifecycle Assessments (LCAs) of two nitrogen-fixing inoculant (NFI) application formats — one applied in-furrow at planting and the other as a seed treatment — show very low climate and environmental impacts. Total Global Warming Potential (GWP) per treated acre ranged from 0.475 to 0.670kg CO_2e, compared to an estimated 70–100+ kg CO_2e per acre for synthetic nitrogen fertiliser production and use (CarbonChain, 2023; Zhang et al., 2022). Other impact categories, including eutrophication (1.3–1.4×10^{-3} kg N eq), acidification (~2.2×10^{-3} kg SO_2 eq), and water use (0.008–0.017m^3), were also minimal across both delivery types. While packaging and manufacturing accounted for a larger share of impacts in the seed-applied format, both formats avoid the high emissions associated with fossil-based nitrogen production and field-phase nitrous oxide losses. Overall, the LCA data support the conclusion that NFI solutions can deliver nitrogen with relatively low lifecycle impacts across a range of environmental impact categories.

Reduced Water Usage from Manufacturing Fertilisers. The production of synthetic N-fertilisers is highly water-intensive, requiring significant volumes for ammonia production, urea synthesis and nitrate-based fertilisers. For example, production of 1 metric tonne of ammonia uses about 7600 gallons of water.[12] In contrast, microbial nitrogen fixation solutions have a substantially lower water footprint at 7 gallons of water per 1 metric tonne of Pivot Bio solution (LCA), thus reducing water demand in the agricultural supply chain. This benefit aligns with water conservation goals, particularly in water-scarce regions where fertiliser production competes with other critical water uses. For 2024, estimated avoided manufacturing water use from the company's NFI solutions stands at 331 million gallons.

Environmental Benefits from Reduced Nitrate Leaching (Estimated). Reduced Nitrate Leaching (Estimated): In addition to N_2O emissions from nitrate leaching, reduced synthetic nitrogen fertiliser use can lower the risk of groundwater and surface water contamination. This can contribute to improved water quality, reduced eutrophication in nearby aquatic ecosystems and potential benefits to biodiversity and human health. While the environmental outcomes are not directly quantified in this methodology, these co-benefits are recognised as important side effects of reducing excess nitrogen inputs. For 2024, estimated avoided nitrate loss (tNO_3) is calculated as 51,392,60 tNO_3 based on an estimate of 48,372,60 tNO_3 nitrate leaching and NO_3-N of 11,609,42 t, using IPCC default rate of 24%.

Biodiversity. Nitrogen-fixing inoculant (NFI) solutions are designed to replace a portion of synthetic nitrogen fertiliser by delivering nitrogen through microbial activity at the plant root. Unlike conventional inputs, these microbes do not introduce inorganic nitrogen directly into the environment, potentially reducing nitrogen runoff and volatilisation. According to scientific research to date in this emerging field, the microbial strains used in NFI products do not persist outside the rhizosphere, and no adverse impacts on soil biodiversity or broader ecosystems have been observed. However, ongoing study is recommended to further validate long-term ecological outcomes across diverse geographies and soil types. Scientific understanding of the soil microbiome remains limited, particularly regarding the functional roles of many microbial species and their interactions with agricultural systems. In contrast, nitrogen from synthetic fertilisers is well-documented to leach into waterways and volatilise into the atmosphere, where it can be redeposited in nitrogen-limited ecosystems. This excess nitrogen contributes to ecological disruption, including harmful algal blooms, reduced soil microbial diversity and shifts in plant community composition that can favour non-native species. Although the economic

[12] The Fertilizer Institute (2022). Sustainability in the Fertilizer Industry. https://www.tfi.org/sustainability

consequences of biodiversity loss are difficult to quantify, its effects on ecosystem stability and function are widely recognised — particularly in the context of exceeding the planetary boundary for biosphere integrity.

Validation & Verification

The ISO 14044 Lifecycle Analysis was conducted by a third-party, SCS Global Services, in July 2024 and updated January 2025. As of this publication, no further third-party validation or verification of avoided emissions methodology or calculations are in place.

Case Study Reflections

In preparing this illustrative case study, members of the Impact Convergence Forum (ICF) share the following reflections:

- Neither Project Frame nor WBCSD support calculation and disclosure of cumulative Realised Impact estimates. However, many Private Equity investors (GPs and LPs) frequently seek to consider total impact that occurs during an investment hold period. **In this case, ICF recommends sharing cumulative Realised Impact estimates only if annual year-on-year estimates are clearly provided as support.**
- **ICF recommends a convergence and alignment of nomenclature for solution types and type of substitution categorisation across Project Frame and WBCSD**. It is our recommendation to adopt language that will be consistent with the GHG Protocol and potential future standards for avoided emissions.
- **Balancing rigour with pragmatism**. As potential impact is often calculated ex-ante (before investment decision made), it is common for the investor to have limited company data or access to extensive product-level LCA information. In the case of Private Equity investors, this type of forward-looking 'back-of-the-envelope' analysis is often done over a time horizon that includes both the hold period and an equivalent post-exit period. Project Frame recommends a longer time horizon for Potential Impact, ideally to 2040 or 2050, to enable greater comparability against other climate solutions, and therefore that time horizon is included in this example. However, it may be the case that PE investors choose a shorter time horizon against which to assess Potential Impact (absent company-specific commercial growth data).
- ICF notes the **best practice of having a written and transparent GHG Calculation Methodology**, with a clear process for updating the methodology at regular intervals. In this case, Pivot Bio updates its GHG Calculation Methodology annually at the start of each growing season to align with the latest science.
- ICF acknowledges that developing a case study of this nature is time-consuming, taking several months. We have erred on the side of completeness for illustrative purposes.
- In this case study, ICF chooses to illustrate Potential, Planned and Realised avoided emissions assessments as a progression of evolving assumptions and GHG calculation methodology maturity, in order to convey a practical example of how these assessments often evolve over time with improved inputs and more detailed methodological choices. **ICF recommends considering a stated tolerance threshold (e.g., ±5%) for material changes in emissions factors or core assumptions.** If updates exceed this threshold, a full recalculation of both annual and cumulative avoided emissions should be triggered to maintain transparency and integrity in reporting.

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Their contributions reflect a range of perspectives and expertise, but this does not imply endorsement of the analysis, conclusions or methodology presented herein. The case study is intended as an illustrative example to surface key methodological questions and considerations in avoided emissions analysis. As such, this case study does not constitute commercial or financial advice or projections.